

AORTA CROSS CLAMP ASSEMBLY

BACKGROUND OF THE INVENTION

1. Reference to Pending Application.

The present application claims priority from, and incorporates by reference,
5 -provisional application serial no. 60/181,435, filed February 10, 2000 by Albert N.
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2. Field of the Invention.

The invention relates to clamps for surgical procedures and, more specifically, to
a clamp assembly especially useful for clamping the ascending aorta during cardiac
10 surgery.

3. Description of the Prior Art.

During the course of cardiac surgery in which cardiac function is arrested, it is
necessary to isolate the heart and coronary blood vessels from the remainder of the
circulatory system. Circulatory isolation of the heart and coronary blood vessels is
15 usually accomplished by placing a mechanical cross clamp externally on the ascending
aorta downstream of the ostia of the coronary arteries, but upstream of the
brachiocephalic artery so that oxygenated blood from the cardiopulmonary bypass
system reaches the arms, neck, head, and remainder of the body. Using conventional
techniques, the sternum is cut longitudinally (a median sternotomy) thereby providing
20 access between opposing halves of the anterior portion of the rib cage to the heart and
other thoracic vessels and organs. Alternatively, a lateral thoracotomy is formed,
wherein a large incision is made between two ribs and the ribs are retracted. A portion
of one or more ribs may be permanently removed to optimize access.

Regardless of whether a sternotomy or a thoracotomy is performed (both collectively referred to herein as a "gross thoracotomy"), the opening in the chest wall must be large enough to permit a cross clamp to be placed externally on the ascending aorta, thereby isolating the heart and coronary arteries from the remainder of the arterial system. A problem with existing cross clamps is their excessive size. A cross clamp usually includes a clamping portion from which integral actuating handles project. The clamp occupies a relatively large portion of the operative site, thereby requiring that the sternum or ribs be retracted to a greater extent than is desired. This is a significant factor in open-chest surgery, because the trauma caused by creating large openings in the chest wall often entails weeks of hospitalization and months of recuperation time.

Recently, techniques have been developed to facilitate the performance of cardiac procedures such as heart valve repair and replacement, coronary artery bypass grafting, and the like, using minimally invasive techniques that eliminate the need for a gross thoracotomy. Coronary artery bypass grafting, heart valve repair and replacement, and other procedures can be performed through small incisions or cannulae positioned in the chest wall. In one recently developed technique, a clamp is introduced into the patient's thoracic cavity through a percutaneous intercostal penetration in the patient's chest, typically using a trocar sleeve. The clamp is detachably mounted to the distal end of a clamp positioner. After the clamp is positioned around the ascending aorta, the clamp is actuated from outside the patient's thoracic cavity to squeeze the aorta and partially or completely block fluid flow

therethrough. The clamp then is disengaged from the distal end of the clamp positioner and the clamp positioner is removed from the thoracic cavity to provide enhanced access to the region in question.

Although the referenced device permits cardiac surgery to be conducted with
5 significantly smaller openings formed in the chest wall, there is a concern about the reliability of the clamp and whether a connection can be reestablished between the clamp and the clamp positioner when it is necessary to remove the clamp. A failure of the clamp or the inability to remove the clamp could have disastrous consequences for the patient.

10 Despite the advantages of minimally invasive cardiac surgery, certain situations still call for the use of a gross thoracotomy. In such circumstances, there remains a need for an aorta cross clamp that is smaller than existing cross clamps but which is extremely reliable and easy to use. In those cases where minimally invasive surgery is indicated, there is a need for an aorta cross clamp that is easy to apply to the
15 ascending aorta, which is reliable in use, and which can be removed without fail.

SUMMARY OF THE INVENTION

In response to the foregoing concerns, the present invention provides a new and improved aorta cross clamp assembly. In one embodiment especially suited for use during a gross thoracotomy, a clamp having movable jaws is provided with a removable
20 actuator having movable handles. Initially, the actuator is connected to the clamp with the jaws in an open position. When the actuator handles are closed, the jaws also will be closed. The clamp is provided with a toothed retainer that prevents the jaws from

being opened accidentally. The actuator can be detached from the clamp and removed from the operative site, leaving the locked clamp in place. When it is desired to remove the clamp, the actuator can be reattached to the clamp and used to disengage the toothed retainer. The actuator then can be used to spread the jaws in order to permit
5 the clamp to be removed.

The clamp and the actuator are provided in two forms. In one form, the toothed retainer is engaged and disengaged by movement toward and away from the jaws ("horizontal" movement). In the other form, the toothed retainer is engaged and disengaged by movement generally perpendicular to the jaws ("vertical" movement).

10 In another embodiment especially suited for use during a minimally invasive surgical procedure, a clamp having movable jaws is provided with a slender, flexible, actuator that is not intended to be removed during use. The actuator has a proximal end that defines a handle and a distal end that is connected to the clamp. The jaws are actuated by axial movement of a screw that is connected to the end of a cable included
15 as part of the actuator. The screw passes through a slotted nut that permits non-rotational axial movement of the screw in one direction, but which requires that the screw be rotated in order to move in the opposite direction. A stem having a knob is attached to the proximal end of the cable and extends outwardly from the handle.

20 When the knob is pushed inwardly (toward the handle), the stem and the cable are advanced, thereby axially moving the screw and closing the jaws of the clamp. The nut prevents the jaws from being opened inadvertently. When it is necessary to remove the clamp, the knob is rotated. This causes the stem, cable, and screw to be

rotated. When the screw is rotated, it is moved axially relative to the nut and pulls the jaws to the open position.

The present invention provides an aorta cross clamp that can be used for cardiac surgery during either a gross thoracotomy or a minimally invasive procedure such as a percutaneous intercostal penetration. With any embodiment of the invention, the clamp assembly is compact, reliable, and easy to apply and remove. The foregoing and other features and advantages of the invention will be apparent from an examination of the specification and claims that follow, including the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an aorta clamp assembly according to the invention especially adapted for use during a gross thoracotomy in which a clamp is disposed adjacent an actuator;

FIG. 2. is a top plan view of the clamp assembly of FIG. 1;

FIG. 3. is a side elevational view of the clamp assembly of FIG. 1;

FIG. 4 is a view similar to FIG. 1 showing an alternative aorta clamp assembly according to the invention especially adapted for use during a gross thoracotomy;

FIG. 5 is a top plan view of the clamp assembly of FIG. 4;

FIG. 6 is a side elevational view of the clamp assembly of FIG. 4;

FIG. 7 is a perspective view of an aorta clamp assembly according to the invention especially adapted for use during minimally invasive cardiac surgery in which a clamp is mounted at the end of a flexible actuator;

FIG. 8 is a view similar to FIG. 7 in which the components of the clamp assembly have been separated and spaced apart for purposes of clarity of illustration; and

FIG. 9 is a enlarged plan view, partly in cross-section, of the proximal and distal ends of the actuator of FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1-3, an aorta cross clamp assembly according to the invention is indicated by the reference numeral 10. The clamp assembly 10 is especially adapted for use during a gross thoracotomy. The clamp assembly 10 includes a clamp 12 and an actuator 14. The clamp 12 has a first jaw 16a and a second jaw 18a. A handle 16b having spaced sides is connected to the jaw 16a. The handle 16b includes a formation 16c at its end. The formation 16c has a slotted opening 16d. The second jaw 18a is similar to the jaw 16a. A handle 18b is connected to the jaw 18a and includes a formation 18c at its end. A slotted opening 18d is provided for the formation 18c.

The handle 16b is defined by a pair of spaced sides through which the handle 18b extends. The handles 16b, 18b are joined for pivotal movement by a hinge pin 20. Each of the jaws 16a, 18a is provided with an elastomeric insert 22 that is intended to minimize trauma to the aorta. The inserts 22 are attached to the respective jaws 16a, 18a by fasteners 24. The longitudinal axes of the jaws 16a, 18a and the handles 16b, 18b are disposed relative to each other at an angle within the range of about 25-30 degrees, preferably about 27 degrees, when viewed from the side (FIG. 3).

A curved ratchet bar 26 is connected to the formation 16c by means of a spring mounting 27. The ratchet bar 26 lies in the arc of a circle whose radius is approximately equal to the distance from the hinge pin 20 to the ends of the handles 16b, 18b. The mounting 27 biases the ratchet bar 26 toward the formations 16c, 18c. A plurality of teeth 28 are provided on that portion of the ratchet bar 26 which faces the formations 16c, 18c. A plurality of teeth 30 are provided on the formation 18c and face the teeth 28. The teeth 28, 30 are oriented such that they engage each other when the handles 16b, 18b are attempted to be moved apart, thereby preventing the handles 16b, 18b from being opened. In effect, the handle 18b and the teeth 30 form a pawl that permits closing movement of the jaws 16a, 18a, but which prevents opening movement of the jaws 16a, 18a. When the handles 16b, 18b (and hence, the jaws 16a, 18a) are closed, a small gap 32 (FIG. 2) is formed between the handles 16b, 18b.

The actuator 14 includes first and second handles 34a, 36a having finger loops 34b, 36b at the proximal ends thereof. Arms 34c, 36c are connected to and project from the handles 34a, 36a. A pair of spaced discs 34d, 36d are disposed at the ends of the arms 34c, 36c. The discs 34d, 36d are spaced apart a distance slightly greater than the width of the formations 16c, 18c. The discs 34d, 36d are joined by pins 34e, 36e. The pins 34e, 36e have a diameter slightly less than that of the slotted openings 16d, 18d.

The handles 34a, 36a are joined for pivotal movement by a hinge pin indicated generally by the reference numeral 38. The actuator 14 includes a third handle 40a. The handle 40a has a finger loop 40b at the proximal end thereof. The finger loop 40b

lies in a plane inclined upwardly at an angle within the range of about 15-20 degrees, preferably about 17 degrees, from the plane in which the handle 40a lies. An arm 40c is connected to and projects from the handle 40a. A finger 40d extends from the arm 40c at a right angle to the longitudinal axis of the arm 40c. The diameter of the finger 40d is slightly less than the width of the space 32.

A sleeve 42 is disposed atop the hinge pin 38. The handle 40a extends through the sleeve 42. An enlarged stop 40f is mounted on the arm 40c. A spring 40g is fitted over the arm 40c and engages the sleeve 42 and the stop 40f. The spring 40g biases the finger 40d away from the sleeve 42 (to the left as viewed in FIGS 1-3).

Operation of the Clamp Assembly 10

When it is desired to use the clamp 12 to compress a patient's ascending aorta, the handles 34a, 36a are moved apart (to the dashed line position shown in FIG. 2) so that the pins 34e, 36e can be engaged with the slotted openings 16d, 18d, respectively. The finger 40d will be disposed in that space defined by the handles 16b, 18b, and the ratchet bar 26. When the finger loops 34b, 36b are moved toward each other (to the solid line position shown in FIG. 2), the handles 16b, 18b will be moved toward each other, thereby closing the jaws 16a, 18a. The jaws 16a, 18a will remain closed due to the interaction of the teeth 28, 30. The actuator 14 can be removed from the now-closed clamp 12 by moving the finger loops 34b, 36b slightly apart and thereafter pushing the actuator 14 slightly toward the clamp 12. The actuator 14 then can be moved clear of the clamp 12 by spreading the finger loops 34b, 36b apart.

When it is desired to remove the clamp 12, the foregoing procedure is reversed

so that the actuator 14 is reattached to the clamp 12. If the surgeon's thumb and middle finger have been used to manipulate the actuator 14, the surgeon can then place the index finger in the finger loop 40b and pull the finger loop 40b to the right as viewed in FIGS. 1-3, against the bias exerted by the spring 40g. The finger 40d will
5 engage the ratchet bar 26, causing the teeth 28, 30 to be disengaged. Thereafter, the finger loops 34b, 34c can be spread apart in order to open the jaws 16a, 18a. The clamp assembly 10 then can then be removed from the operative site.

A Second Embodiment

Referring now to FIGS. 4-6, an alternative aorta clamp assembly especially
10 adapted for use during a gross thoracotomy is indicated by the reference numeral 50. The clamp assembly 50 includes a clamp 52 and an actuator 54. The clamp 52 has a first jaw 56a and a second jaw 58a. A curved handle 56b is connected to the first jaw 56a. The handle 56b includes an upper, curved bar 56c at its end and a lower, curved bar 56d that is parallel to, but spaced from, the upper bar 56c. The second jaw 58a is
15 similar to the arm 56a. A handle 58b is connected to the jaw 58a and includes an upper, curved bar 58c at its end and a lower, curved bar 58d that is parallel to, but spaced from, the upper bar 58c.

A plurality of teeth 60 are provided on the lower bar 56d, while a plurality of teeth 62 are provided on the upper bar 58c. The bars 56c, 58d do not have any teeth. As
20 can be seen in FIG. 4, the bars 56c, 56d, 58c, 58d are fitted together so that the teeth 60, 62 engage each other when the handles 56b, 58b are attempted to be moved apart, thereby preventing the handles 56b, 58b from being opened. In turn, the jaws 56a, 58a

will be prevented from opening. The upper bar 56c is spaced at a small distance from the bar 58c, while the lower bar 56d is spaced a small distance from the bar 58d.

The handles 56b, 58b are joined for pivotal movement by a hinge pin 64. Each of the jaws 56a, 58a is provided with an elastomeric insert 66 that is intended to

5 minimize trauma to the aorta. The inserts 66 are attached to the respective jaws 56a, 58a by fasteners 67. A curved spring 68 is disposed between the handles 56b, 58b and causes the handles 56b, 58b to be biased apart. The longitudinal axes of the jaws 56a, 58a and the handles 56b, 58b are disposed relative to each other at an angle within the range of about 25-30 degrees, preferably about 27 degrees, when viewed
10 from the side (FIG. 6). When viewed from above (FIG. 5), the bars 56c, 56d, 58c, 58d lie in the arc of a circle whose radius is approximately equal to the distance from the hinge pin 64 to the ends of the handles 56b, 58b.

The actuator 54 includes first and second handles 70a, 72a having finger loops 70b, 72b at the proximal ends thereof. A pair of opposed shells 70c, 72c are
15 connected to the handles 70a, 72a, respectively. The shells 70c, 72c are of a size and shape to receive the curved handles 56b, 58b, including the upper and lower curved bars 56c, 58c, 56c, 58d. The handles 70a, 72a are joined for pivotal movement by a hinge pin indicated generally by the reference numeral 74. When the handles 70a, 72a (and, hence, the shells 70c, 72c) are closed, a small gap 75 (FIG. 5) is formed between
20 the shells 70c, 72c.

The actuator 54 includes a third handle 76a having a finger loop 76b at the proximal end thereof. The handle 76a has a generally-ogee-shaped distal end 76c that

includes an axially extending lower portion 76d. The lower portion 76d is adapted to fit into the gap 75 between the closed shells 70c, 72c and engage the lower curved bar 58d.

5 The actuator 54 includes a formation 78 which is connected to the hinge 74. A pair of spaced tabs 80 are included as part of the formation 78. A hinge pin 82 extends through the tabs 80 and the handle 76a. A spring 84 is disposed intermediate the upper surface of the formation 78 and the underside of the handle 76a. The spring 84 biases the handle 76a away from the first and second handles 70a, 72a to that position shown by the solid lines in FIG. 6.

10 Operation of the Clamp Assembly 50

When it desired to use the clamp 52 to compress a patient's ascending aorta, the shells 70c, 72c are disposed about the ends of the curved handles 56b, 58b in the open position. As the handles 70a, 72a are moved toward each other, the jaws 56a, 58a will be moved to the solid line position in FIG. 5. After the handles 70a, 72a have
15 been moved apart and the shells 70c, 72c have been removed from the handles 56b, 58b, the clamp 52 will remain in the closed position shown by the solid lines in FIG. 5 due to the engagement between the opposed teeth 60, 62.

When it is desired to remove the clamp 52, the foregoing procedure is reversed and the handle 76a is pressed towards the handles 70a, 72a. The lower portion 76d
20 will be pivoted into contact with the lower curved bar 58d. Continued movement of the handle 76a will cause the upper curved bar 56d to engage the underside of the upper

walls that define the shells 70c, 72c. Thereafter, continued movement of the handle 76a will cause the bars 58c, 56d to be moved relative to each other such that the teeth 60, 62 become disengaged. Under the influence of the spring 68, the handles 56b, 58b (and, hence, the jaws 56a, 58a) will be moved apart as the handles 70a, 72a are

5 Moved apart from each other. After the jaws 56a, 58a have been moved enough to release their grip on the aorta, the clamp 52 and the actuator 54 can be retracted from the operative site.

A Third Embodiment

Referring now to FIGS. 7-9, an aorta cross clamp assembly especially adapted

10 for use during minimally invasive cardiac surgery is indicated generally by the reference numeral 90. The clamp assembly 90 includes a clamp 92 and an actuator 94. The clamp 92 has a cylindrical base 96 with a bore therethrough. A first jaw 98 is rigidly connected to the cylindrical base. A second jaw 100 is pivotally connected to the cylindrical base 96. The connection is established by a slot 102 formed in the first

15 jaw 98. A hinge pin 104 extends through the jaws 98, 100. Each of the jaws 98, 100 is provided with an elastomeric insert 106 that is intended to minimize trauma to the aorta. The inserts 106 are attached to the respective jaws 98, 100 by fasteners 108.

A screw 110 is disposed within the bore. A screw 110 is a so-called quick advance screw having coarse, tapered threads. A slotted nut 112 is connected to the

20 cylindrical base 96 at that end opposite the jaws 98, 100. A link 114 is connected to the jaw 100. The connection is established by a slot 116 formed in the jaw 100 and a pin 118 that is connected to the link 116 which extends through the slot 116. The link

114 is rotatably connected to the screw 110. A drive connector 120 having a plurality of longitudinally extending keyways is connected to the other end of screw 110.

The actuator 94 includes a flexible housing 122. A fitting 124 is connected to the proximal end of the housing 122. A cylindrical, hollow handle 126 is connected to the fitting 124. A pair of finger loops 128 extend from opposite sides of handle 126. A fitting 130 is connected to the distal end of the housing 122. The fitting 124 is releasably connected to the handle 126, while the fitting 130 is releasably connected to the cylindrical base 96. Although the fittings 124, 130 can be disconnected for purposes of cleaning and sterilization, it is expected that they will remain connected as shown in FIG. 7 during the course of a surgical procedure.

An elongate flexible cable 132 extends through the housing 122. A cylindrical stem 134 is connected to the proximal end of the cable 132. A knurled knob 136 is disposed at the end of the stem 134. A splined drive member 138 is connected to the distal end of the cable 132. The splines on the drive member 138 engage the keyways in the drive connector 120 so as to establish a driving connection. As will be apparent from an examination of FIG. 9, the drive member 138 and the connector 120 can be moved axially relative to each other.

Operation of the Clamp Assembly 90

Starting from the position shown FIG. 7, the clamp 92 can be actuated to cause the jaws 98, 100 to clamp an ascending aorta by pushing the stem 134 toward the handle 126 (from the full line position in FIG. 9 to the dashed line position in FIG. 9). When the handle 126 is moved in this manner, the cable 132 is moved within the

housing so that axial force is applied to the connector 120 and, hence, to the screw 110. Due to the orientation of the screw threads relative to the nut 112, the screw 110 will be moved axially, thereby causing the jaw 100 to be pivoted toward the jaw 98. Although the screw 110 can be advanced toward a jaw-closed position without rotation, it cannot be retracted without rotation for two reasons: (1) if the cable 132 is pulled out of the housing 122, the drive member 138 will be disconnected from the drive connector 120, as shown in FIG. 9, and (2) the nut 112 will engage the threads of the screw 110 so as to prevent retraction of the screw 110.

When it is desired to loosen the jaws 98, 100 in order to remove the clamp 92 from the aorta, it is necessary to rotate the knob 136 so that the stem 134, cable 132, drive member 138, connector 120, and screw 110 all are rotated. When the screw 110 is rotated relative to the nut 112, the screw 110 will be retracted from the bore in the base 96, thereby causing the jaw 100 to be pulled toward a jaw-open position. After sufficient movement of the jaw 100 has occurred, the clamp 92 can be removed from the operative site.

It is possible for the various components of the invention to be modified and still produce a satisfactory product. For example, and without limitation as to the type of changes that are within the scope of the invention, the embodiment of FIGS. 1-3 could be provided as a third class lever similar to the embodiment of FIGS. 7-9, that is, the handles 16b, 18b could be eliminated and the ratchet bar 26 and the formations 16c, 18c could be positioned between the hinge pin 20 and the inserts 22. In this case, the ratchet bar 26 would be on the top or bottom of the jaws 16a, 18a or it would extend

through an opening formed in one of the jaws 16a, 18a. The embodiments of FIGS. 4-6 could be reconfigured similarly. The embodiment of FIGS. 7-9 could be provided in the form of a first class lever by connecting a handle to the second jaw 100, in a manner similar to the embodiments of FIGS. 1-3 and 4-6.

5 Although the invention has been described in its preferred form with a certain degree of particularity, it will be understood that the present disclosure of the preferred embodiment has been made only by way of example, and that various changes may be resorted to without departing from the true spirit and scope of the invention as hereinafter claimed. It is intended that the patent shall cover, by suitable expression in
10 the appended claims, whatever degree of patentable novelty exists in the invention disclosed.